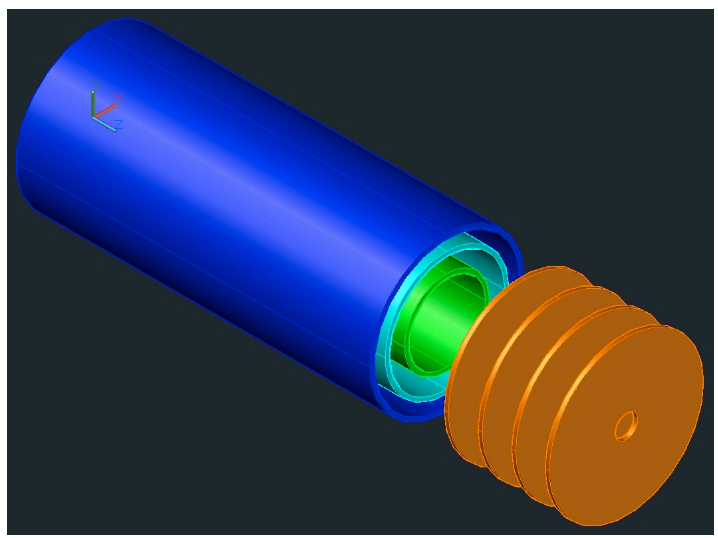
Design and Assembly of fast and light-weight barrel / forward prototype tracking detectors (EIC R&D)

PI Barrel System: Franck Sabatie (Saclay)

and

PI Forward System: Bernd Surrow (MIT / Temple Univ.)



Proposal

Design and assembly of fast and lightweight barrel and forward tracking prototype systems for an EIC

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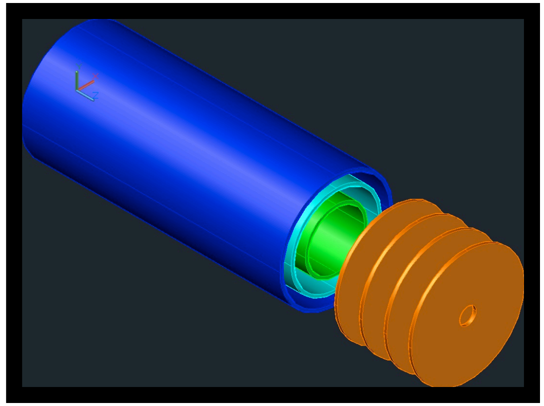
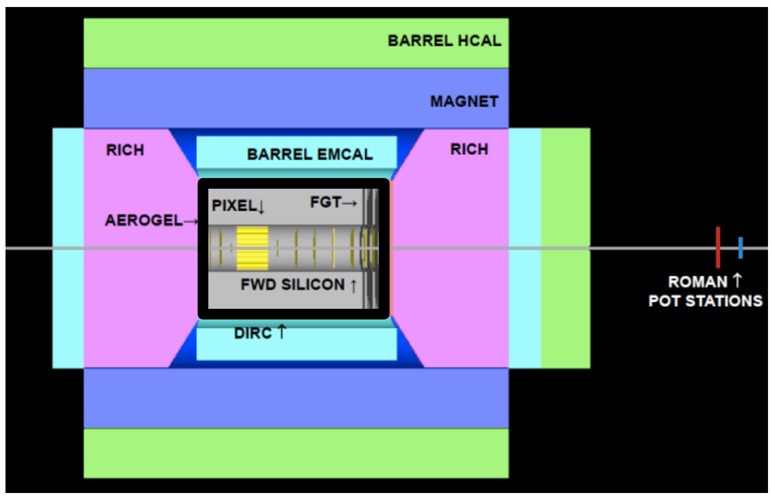
Outline

- Introduction
- **Micromegas Barrel System**
  - Motivation
  - CLAS12 experience
  - R&D plan
  - Institutional background
- **Triple-GEM Forward System**
  - Motivation
  - STAR experience
  - R&D plan
  - Institutional background
- Collaborative efforts
- Research plan / Funding request
- Summary





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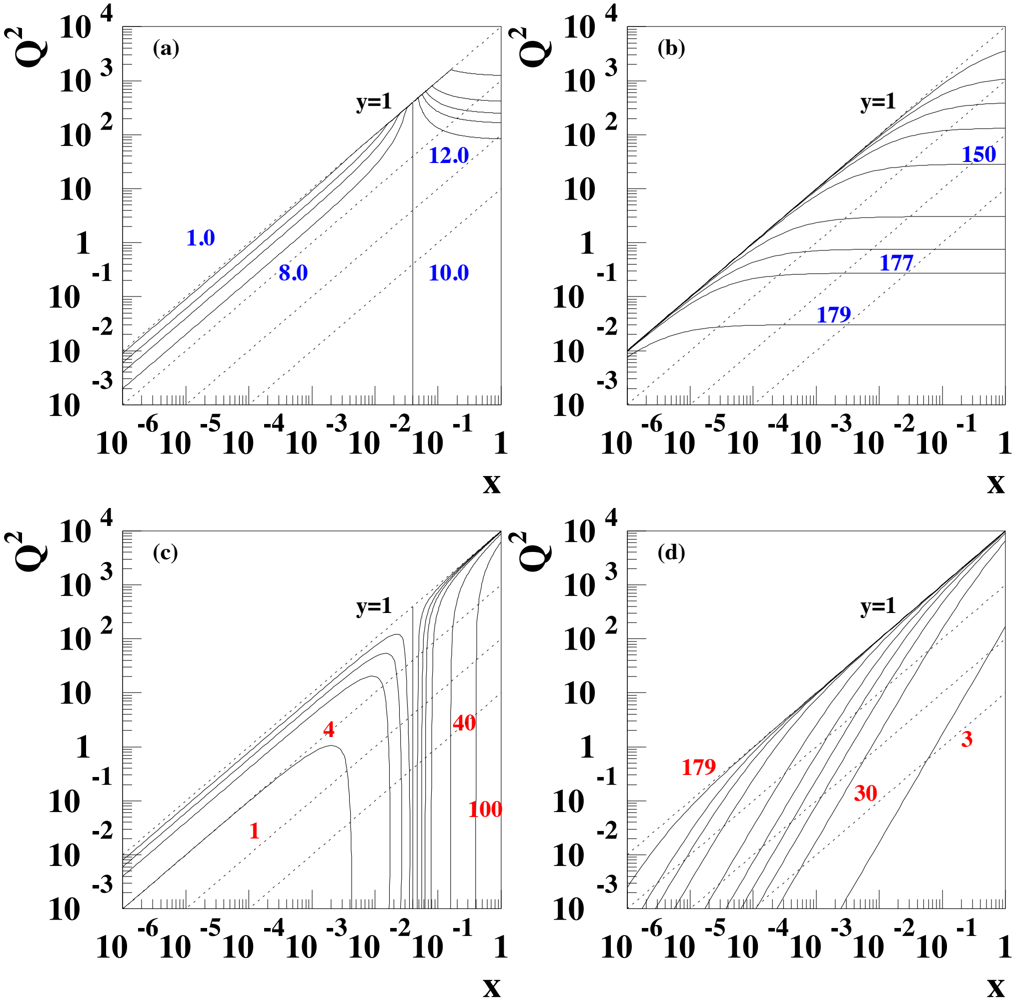
Bernd Surrow (MIT / Temple Univ.)

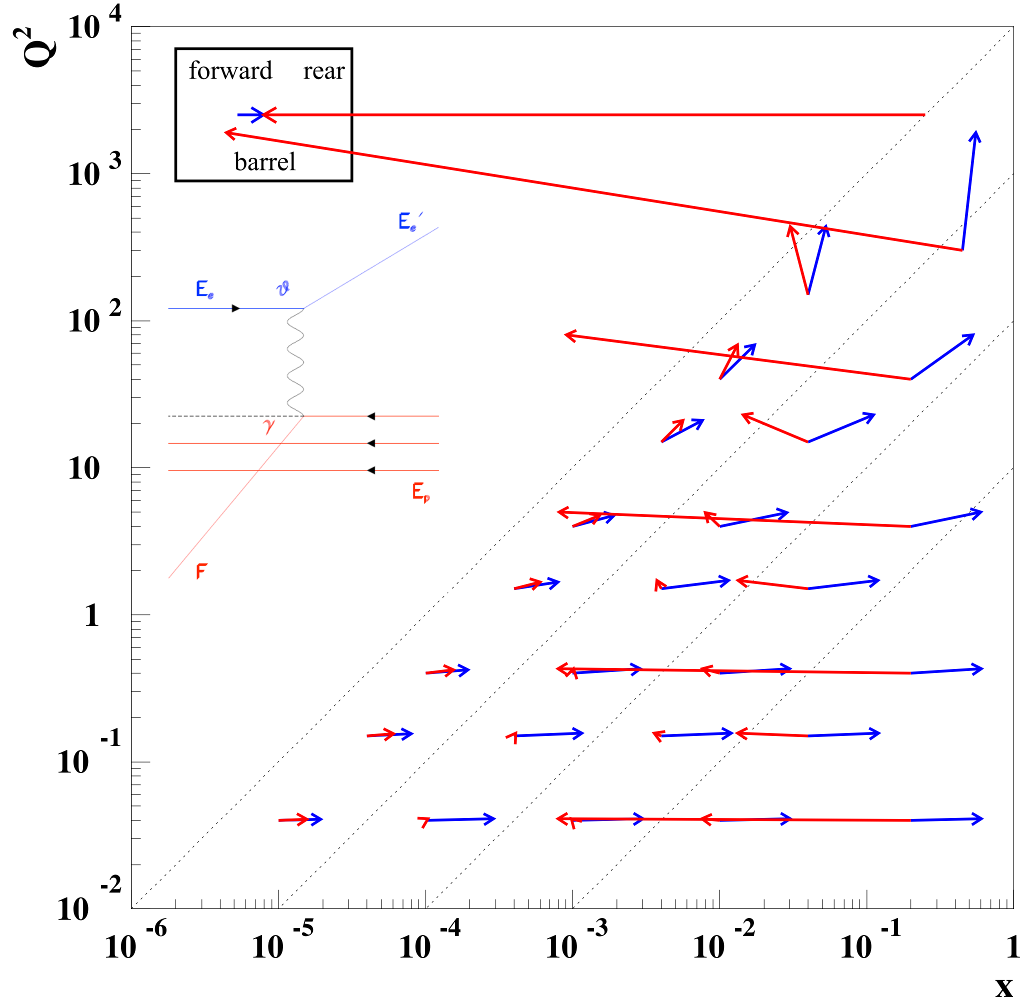
Introduction

- ☐ Remarks on ep Collider Kinematics: 10GeV (e) X 250GeV (p)

EIC kinematics (E_e=10 GeV, E_p=250 GeV)



EIC event topology (E_e=10 GeV, E_p=250 GeV)



$$E_e/E_p = 0.04$$

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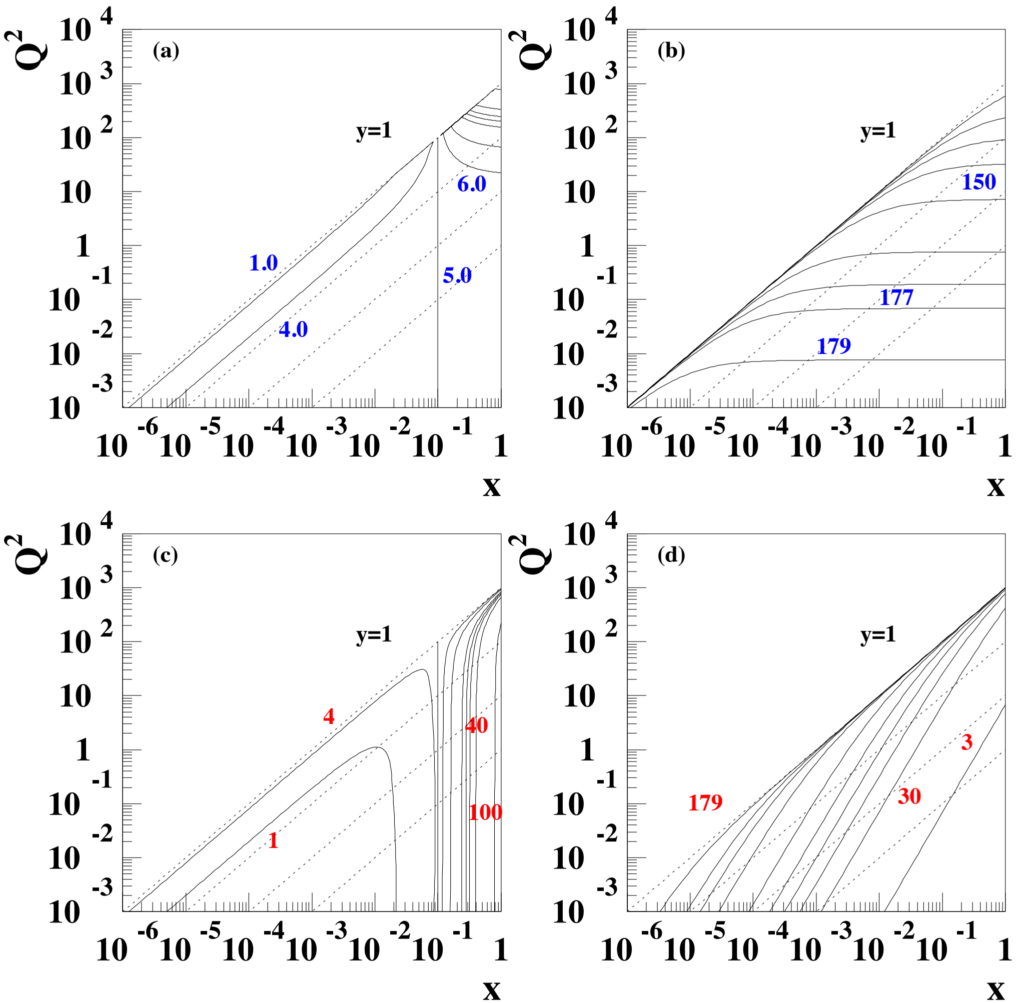
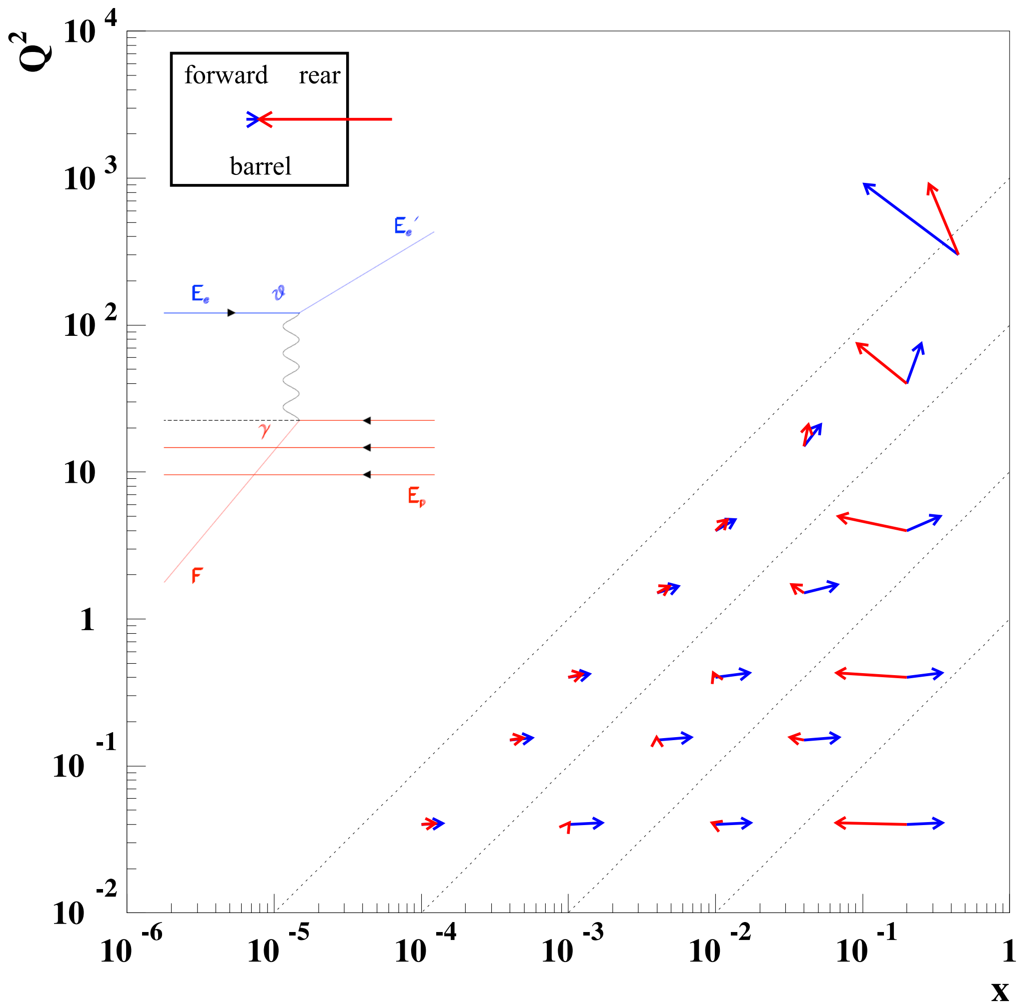
Introduction

- Remarks on ep Collider Kinematics: 5GeV (e) X 50GeV

EIC kinematics (E_e=5 GeV, E_p=50 GeV)



EIC event topology (E_e=5 GeV, E_p=50 GeV)



$$E_e/E_p = 0.1$$

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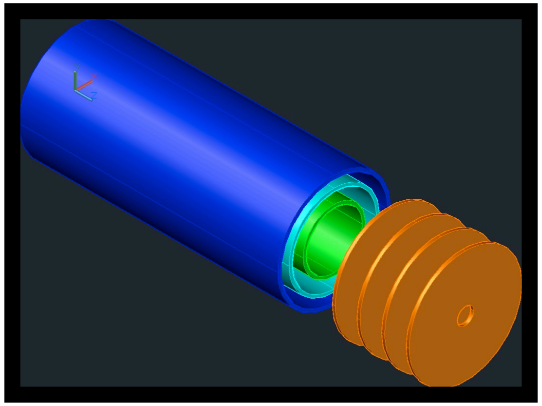
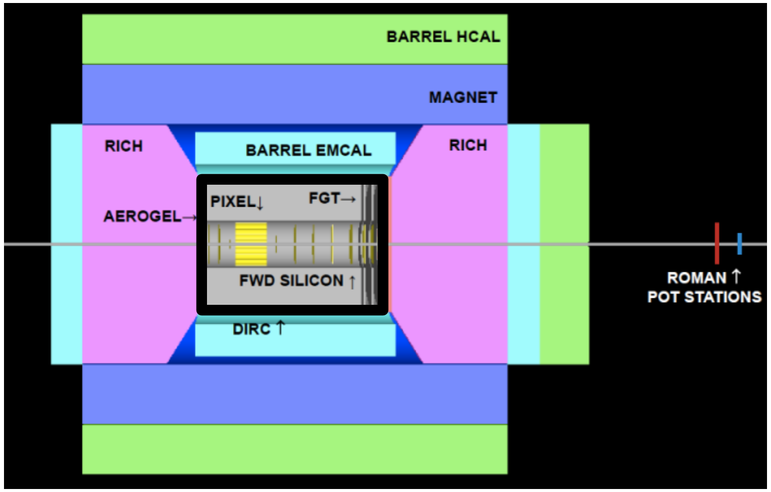
Introduction

- Considerations on Tracking System



  - Tracking over wide acceptance range: Forward with ~1° and Rear with ~179°, excluding very forward/rear detector regions
  - Contribute to reconstruction of event kinematics besides calorimetry in particular at very small energies
  - High-rate environment (~10MHz ep collisions)
  - Fast time response
  - Precision hit resolution, e.g. low Q^2 region
  - Minimal dead material (~1% X_0)
  - Cost effective solution for large tracking detector areas
  - Profit from world-wide micro-pattern detector development (RD51 Collaboration)



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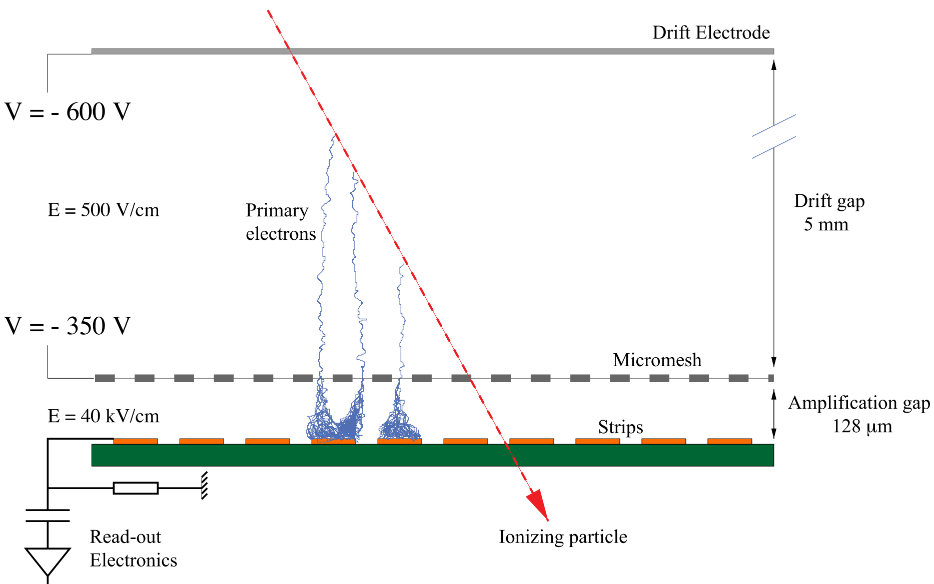
Introduction

Micro-pattern Tracking detector concepts

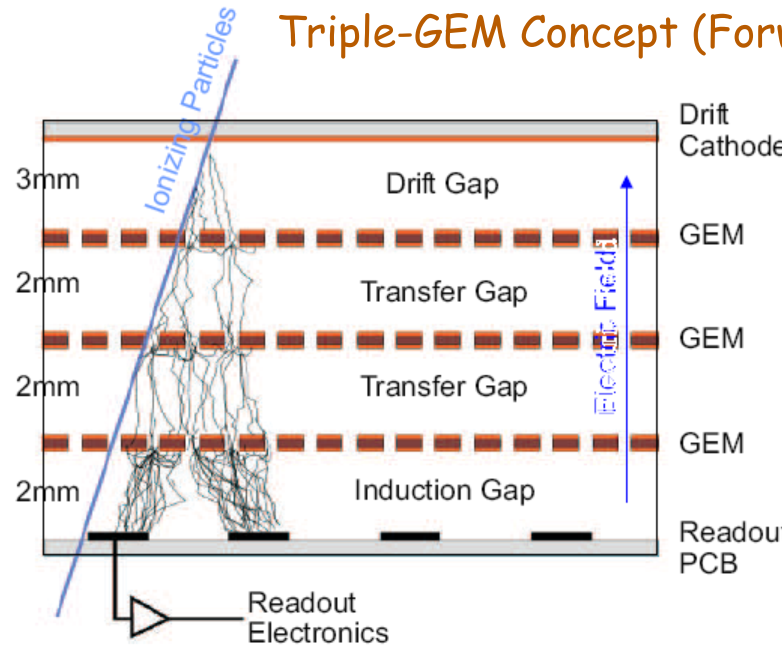
- Fast time response
- Separation of drift region from charge-collection region
- Flexibility in 2D readout structure (planar / cylindrical)
- Enormous progress in principal component production (GEM foil / Micromesh) including commercial fabrication
- Low dead material (< 1% X_0)
- Relatively low material cost per unit area

Micromegas Concept (Barrel)



MICROMEsh GAseous Structure

Triple-GEM Concept (Forward)



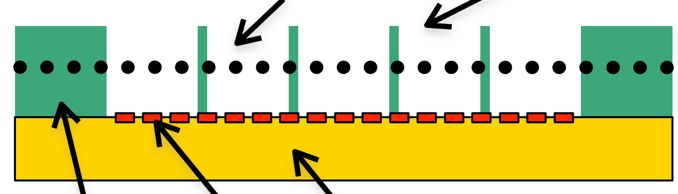
Gas Electron Multiplier

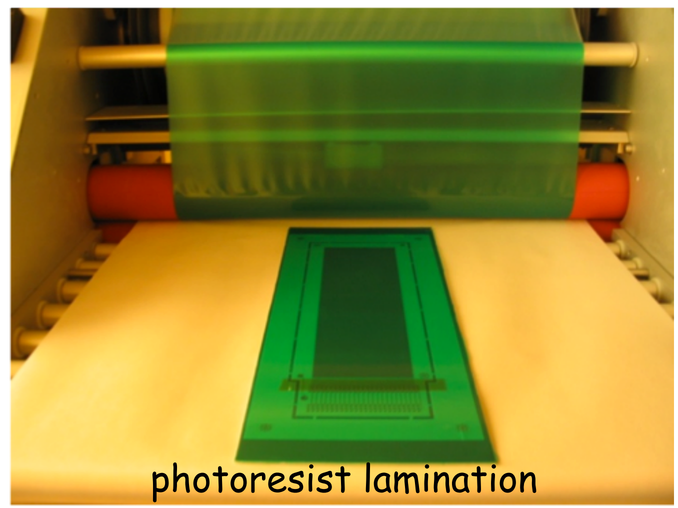
Micromegas Barrel Tracking System - EIC R&D

- Motivation
  - Bulk technology for MICROMEGAS production: Lamination of PCB with photo-resist film
  - Array of spacers ('pillars') support mesh at constant distance to readout plane
  - Large area production possible
  - Complement micro-vertex SI detector at larger radii
  - Cost effective solution for larger radii region
  - Low dead material (~0.3% X_0)
  - Geometry: Progress in cylindrical shape arrangement - Optimized layout

Bulk Technology

(mesh imbedded in photoresist)





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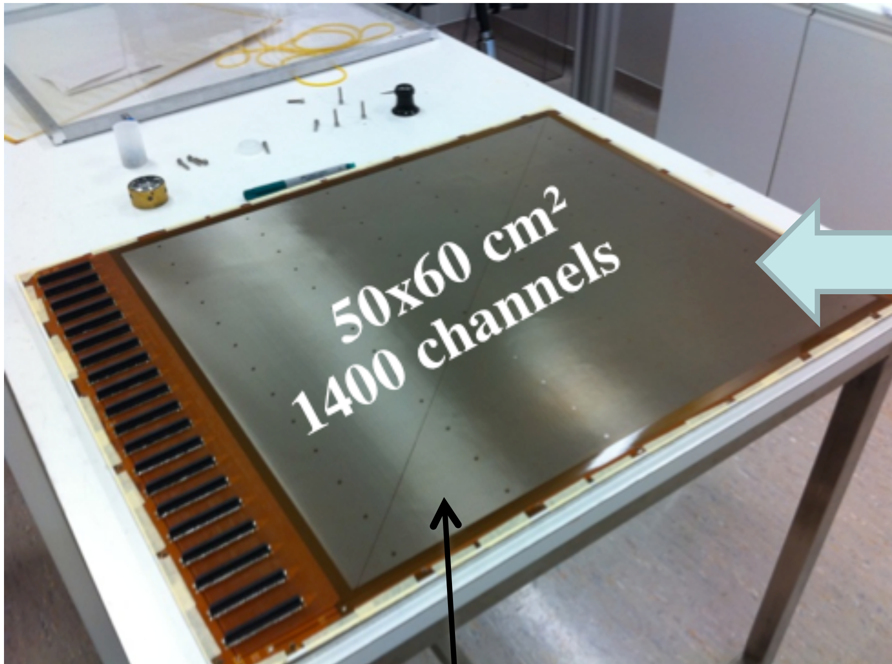
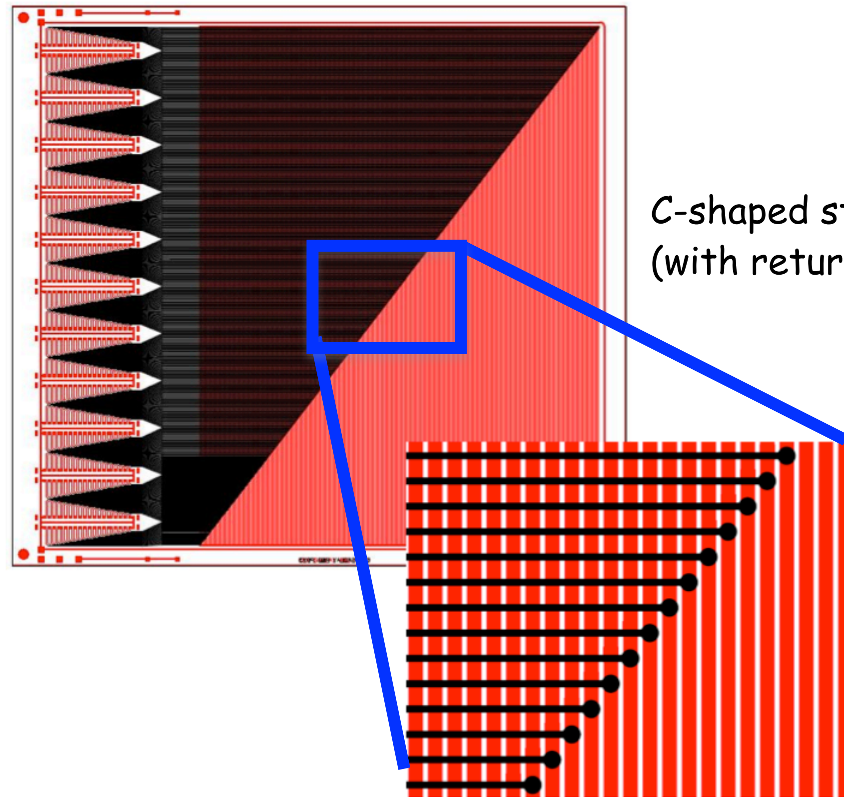
Micromegas Barrel Tracking System - EIC R&D

- Barrel system: CLAS12 Experience (1)

CLAS12





C-shaped strips
(with return strips)

Largest
flexible MM
ever built

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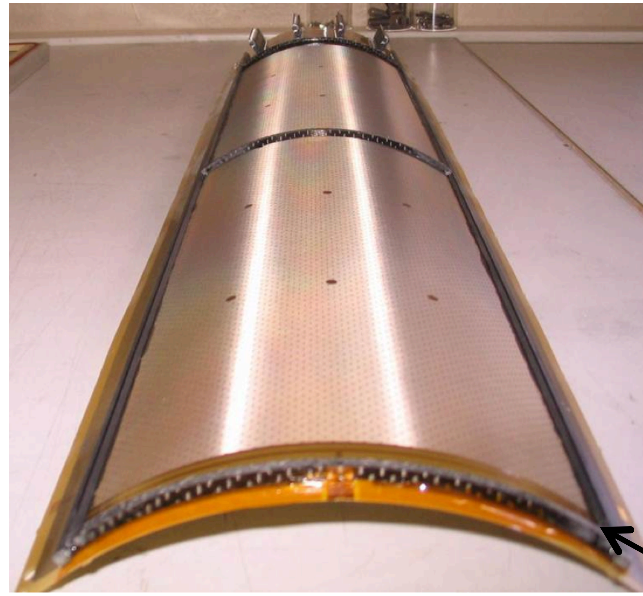
Micromegas Barrel Tracking System - EIC R&D

- Barrel system: CLAS12 Experience (2)

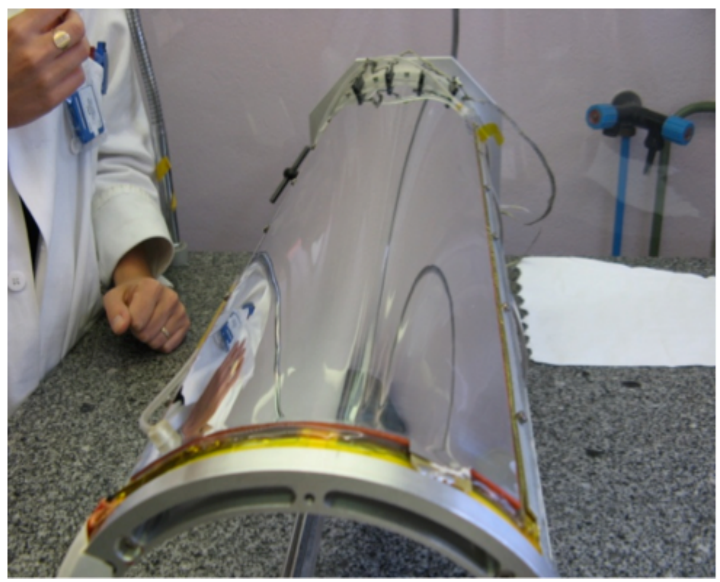
CLAS12

CLAS12 (Start 2015)
Barrel Vertex Tracker:

- R up to ~25cm, L~45cm
- 30k channels
- Self-supporting tiles
- Low material budget
- 100~200 μm resolution
- Designed for use in 5T
- 1.5m flex cable to FEE



Carbon Composite structure



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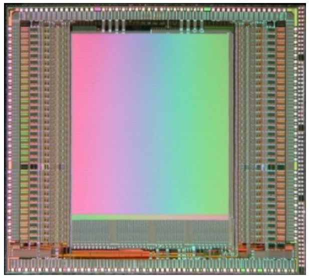
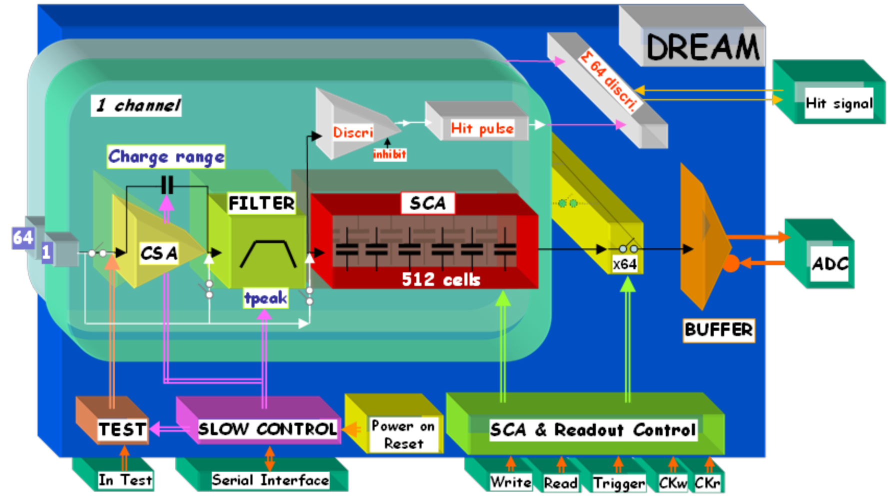
Micromegas Barrel Tracking System - EIC R&D

- Barrel system: Front-End Electronics

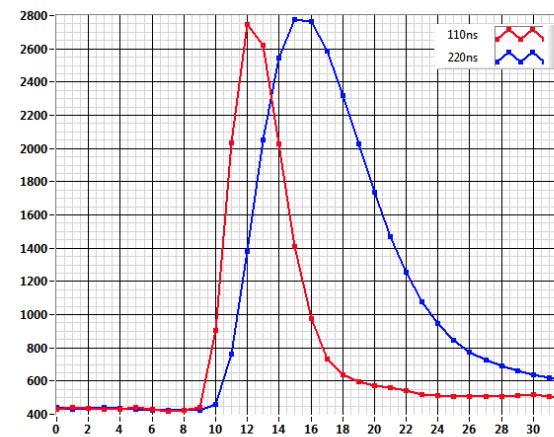


AMS 0.35μm, 700.000 transistors

14 mm x 14 mm package



- APV-like chip: DREAM (CLAS12 development)
  - 512 cells / channel
  - Low noise
  - Analogue multiplexed output
  - Optimized for large detector capacitance, 50-200pF
  - Latency up to 16μs



~25fC Test pulses measured with DREAM
(110 & 220ns shaping , 50fC range)

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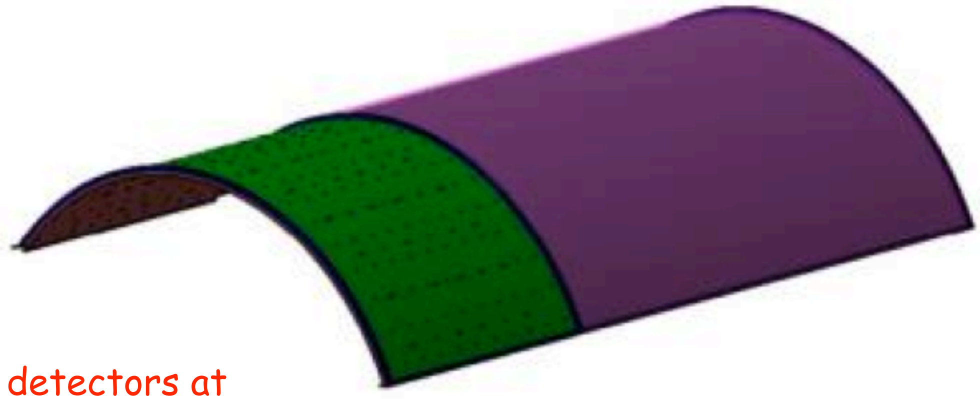
Micromegas Barrel Tracking System - EIC R&D

- Barrel system: R&D
  - Specifications of a new EIC R&D prototype:
    - Dimensions: R~50cm, L~100cm, $\Delta\phi$=60°
      (x2 wrt CLAS12, needs R&D)
    - Design, production and testing MICROMEGAS detectors at Saclay workshop
    - Imbedded DREAM electronics
      (with 200μm PCB : needs R&D)
      or External readout with long flex cables
      (R&D on very large acceptance detector S/N optimization)
    - Self-trigger capabilities of DREAM
      (R&D on front-end board)
  - Request: 75k$ (FY12/FY13)
    - Labor: 50k$
    - Material (Prototype with electronics): 25k$



Building a full prototype segment essential:

- Mechanics
- Micromegas
- Readout structure
- FEE

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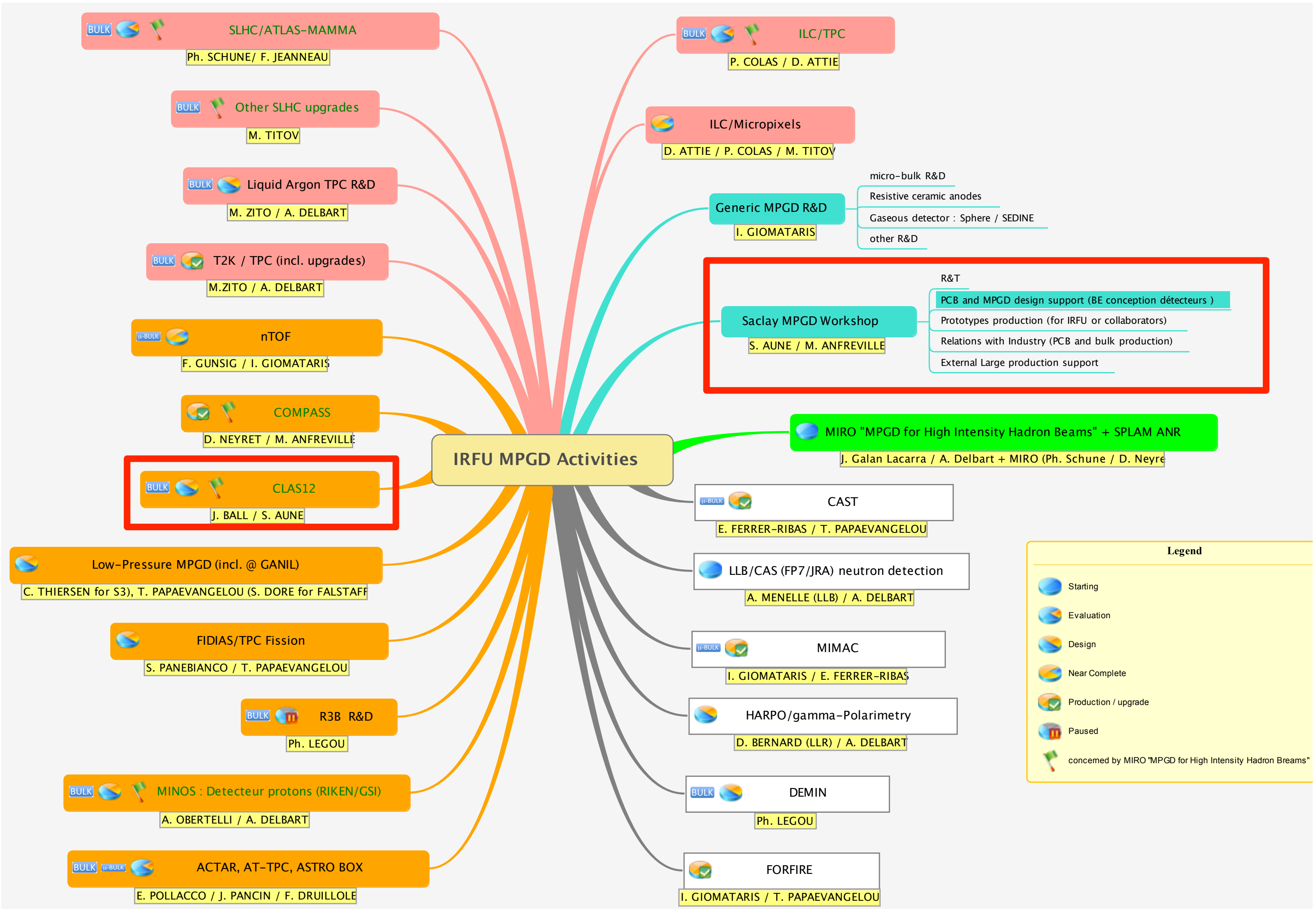
Micromegas Barrel Tracking System - EIC R&D

- Barrel system: Saclay group experience and resources



Leadership in MPGD technology :

- R&D
- Infrastructure
- Key personnel involved in various world-wide applications
- Key person for EIC prototype production

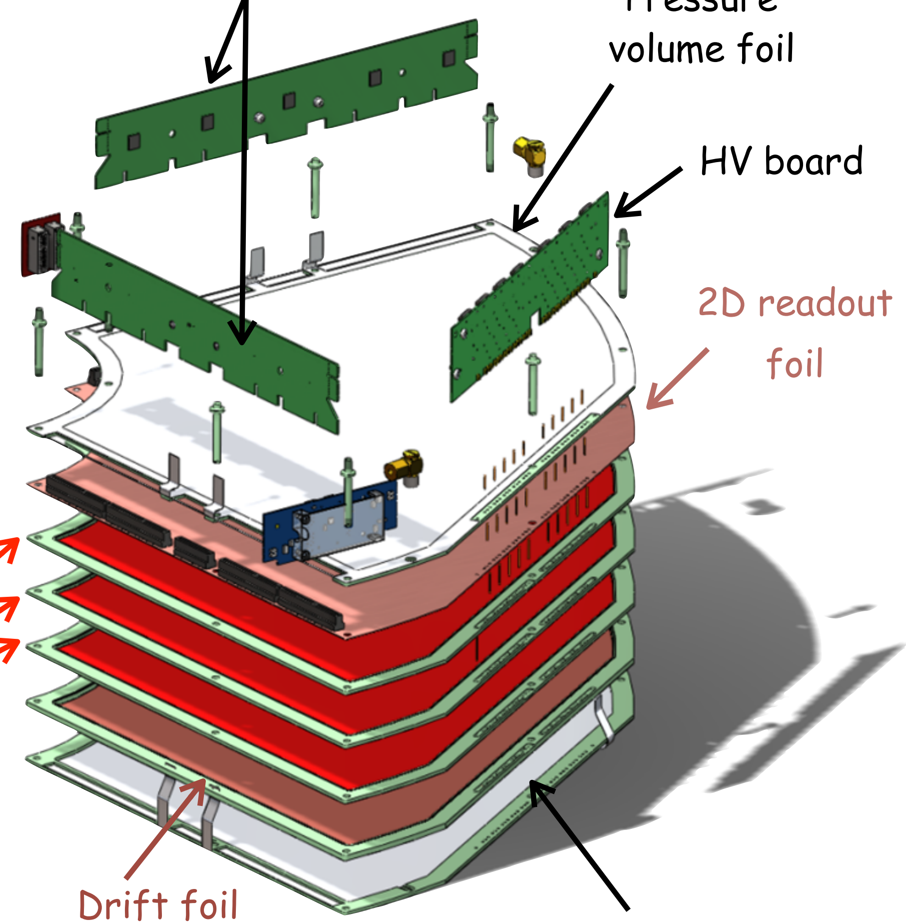
Triple-GEM Forward Tracking System - EIC R&D

- Motivation
  - Triple-GEM application by various experiments
  - Advantages:
    - Reliable (COMPASS, multi-year experience)
    - High gas amplification (Multiple GEMs: up to ~10^6)
    - Fast time response
    - Low mass (< 1% X0)
    - Good spacial resolution (1D and 2D) (~60μm)
    - Relatively low material cost

F. Sauli, Nucl Instr. and Meth. A386 (1997) 531.

C. Altunbas et al., Nucl Instr. and Meth. A490 (2002) 177.

B. Surrow et al., Nucl Instr. and Meth. A617 (2010) 196.



STAR Forward GEM Tracker

Triple-GEM Detector / Quarter Section Arrangement

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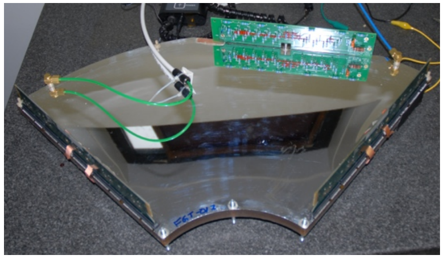
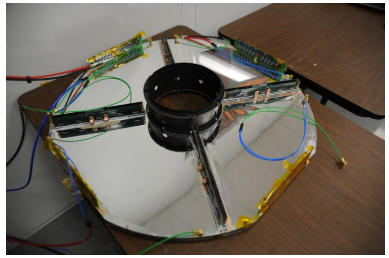
Bernd Surrow (MIT / Temple Univ.)

Triple-GEM Forward Tracking System - EIC R&D

- Forward system: STAR Experience

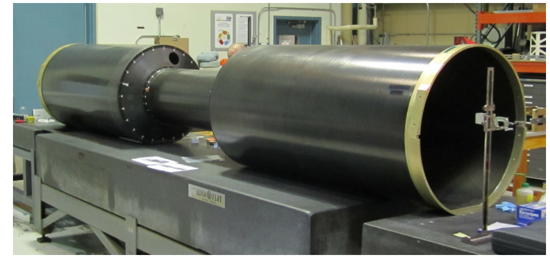


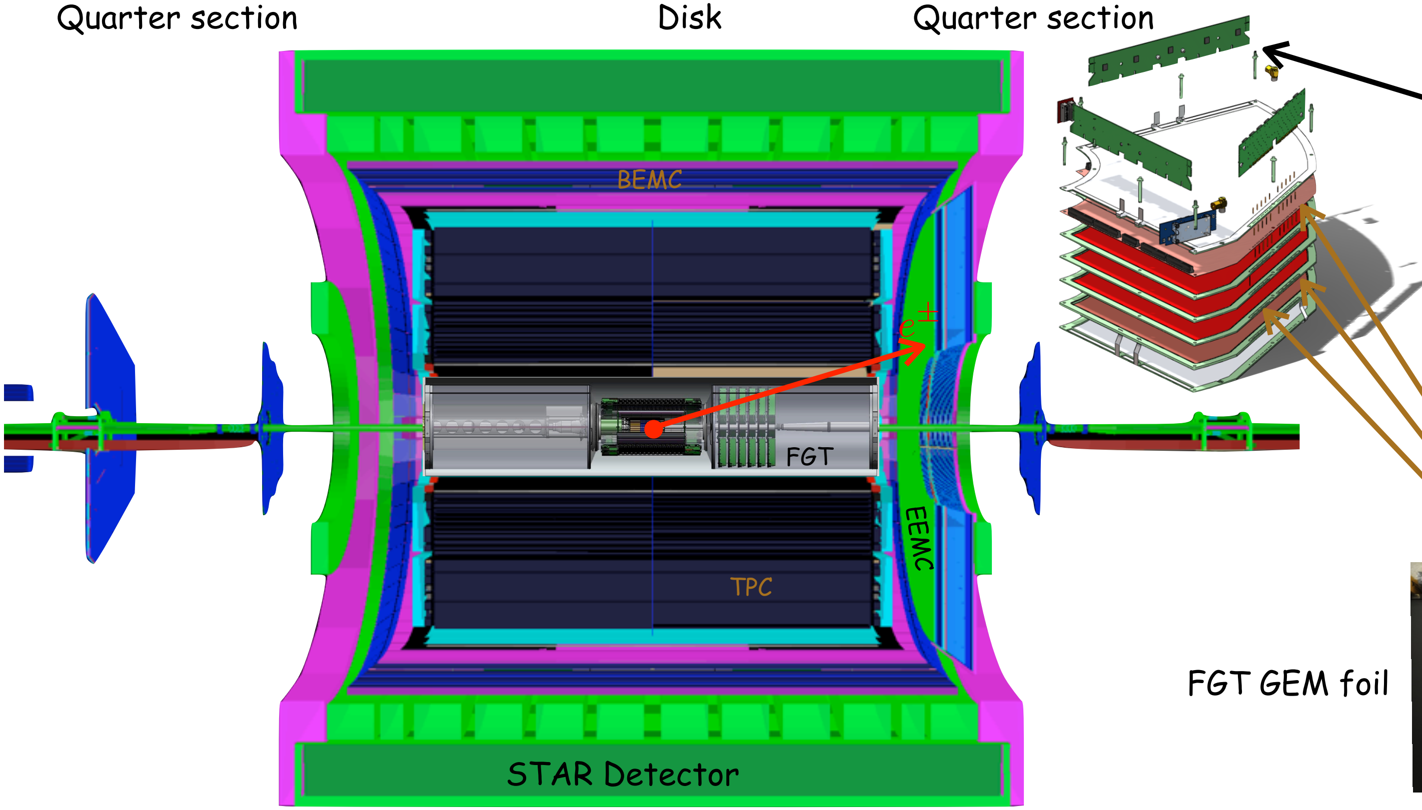
Quarter section



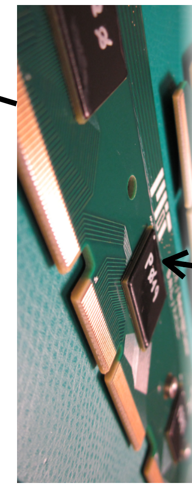
Disk

Quarter section





APV module



Packaged APV chip

FGT GEM foil

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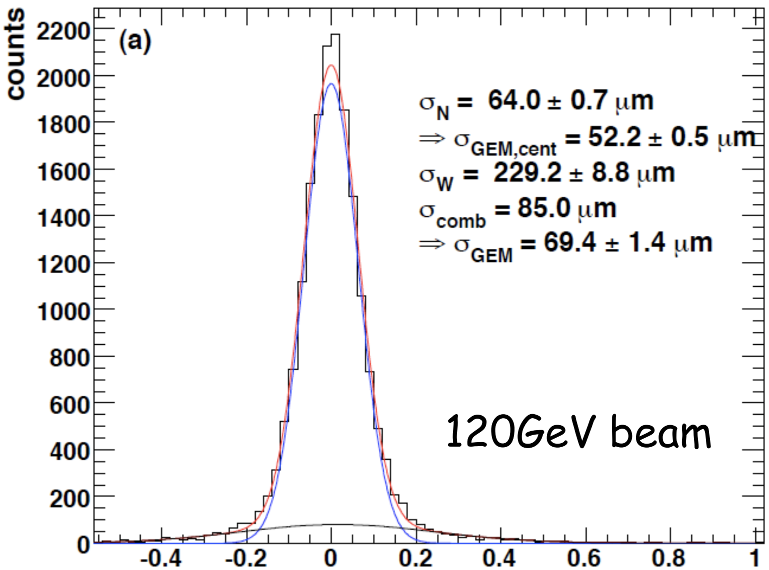
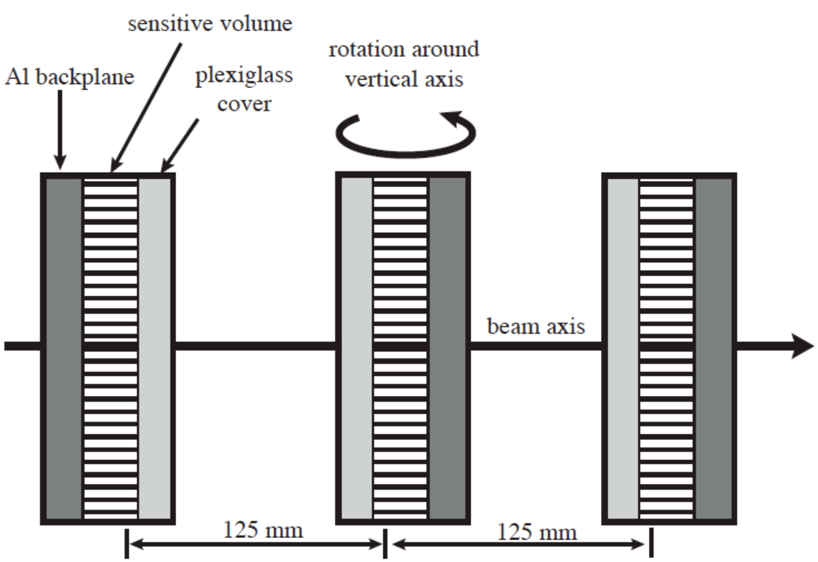
Triple-GEM Forward Tracking System - EIC R&D

- Forward system: Commercial fabrication of GEM foils - STAR Experience



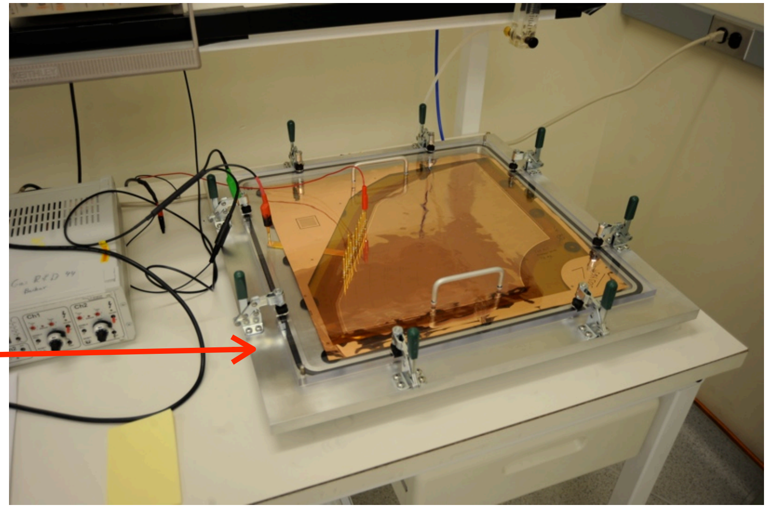


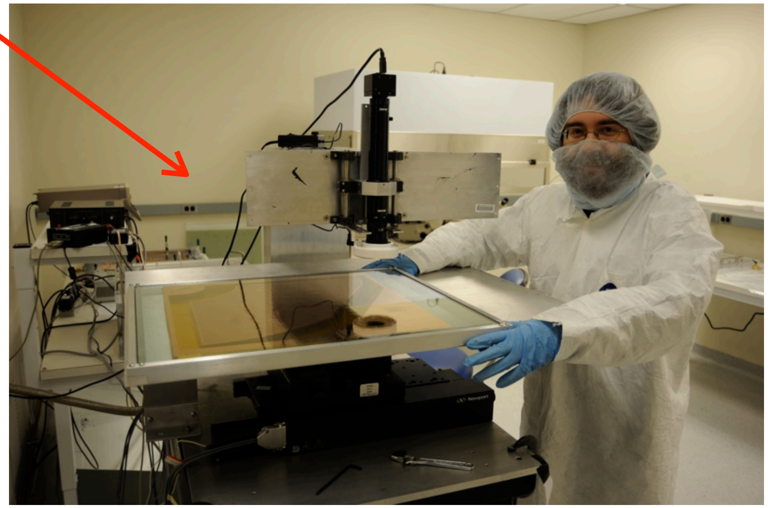
- Extensive R&D program comparing CERN and commercial produced GEM foils by Tech-Etch Inc. (Optical uniformity, source scan of triple-GEM prototypes, test-beam)
- Commercial fabrication of 2D readout board (First generation laser etching by Compunetics Inc. / New: Novel chemical etching technique by Tech-Etch Inc. - foil using VIAS connections)

Franck Sabatie (Saclay)
Bernd Surrow (MIT / Temple Univ.)

Triple-GEM Forward Tracking System - EIC R&D

- Forward system: Large GEM foil development - STAR Experience
  - Extensive R&D program comparing CERN and commercial produced GEM foils by Tech-Etch Inc. of larger size
  - Leakage current measurements: Critically depending on cleaning and handling process
  - Optical uniformity measurements: Tech-Etch Inc. using glass-mask setup - Superior compared to CERN produced double-etching technique foils
  - Next SBIR initiative: Commercial production of single-masked produced large foils by Tech-Etch Inc. (Long term effort)





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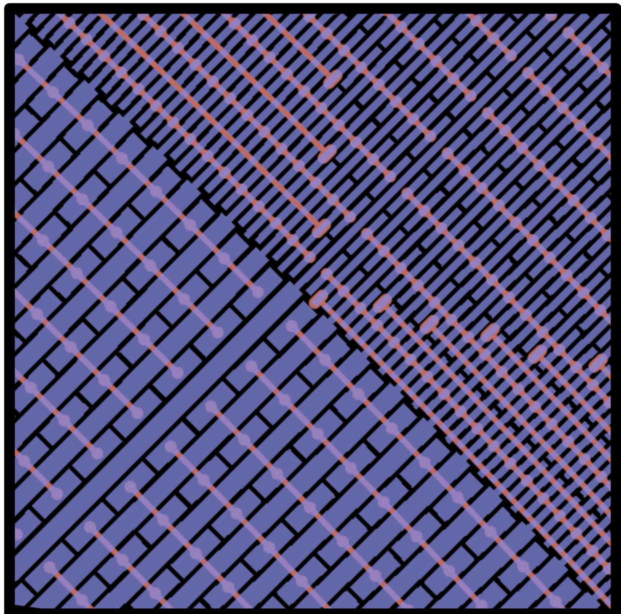
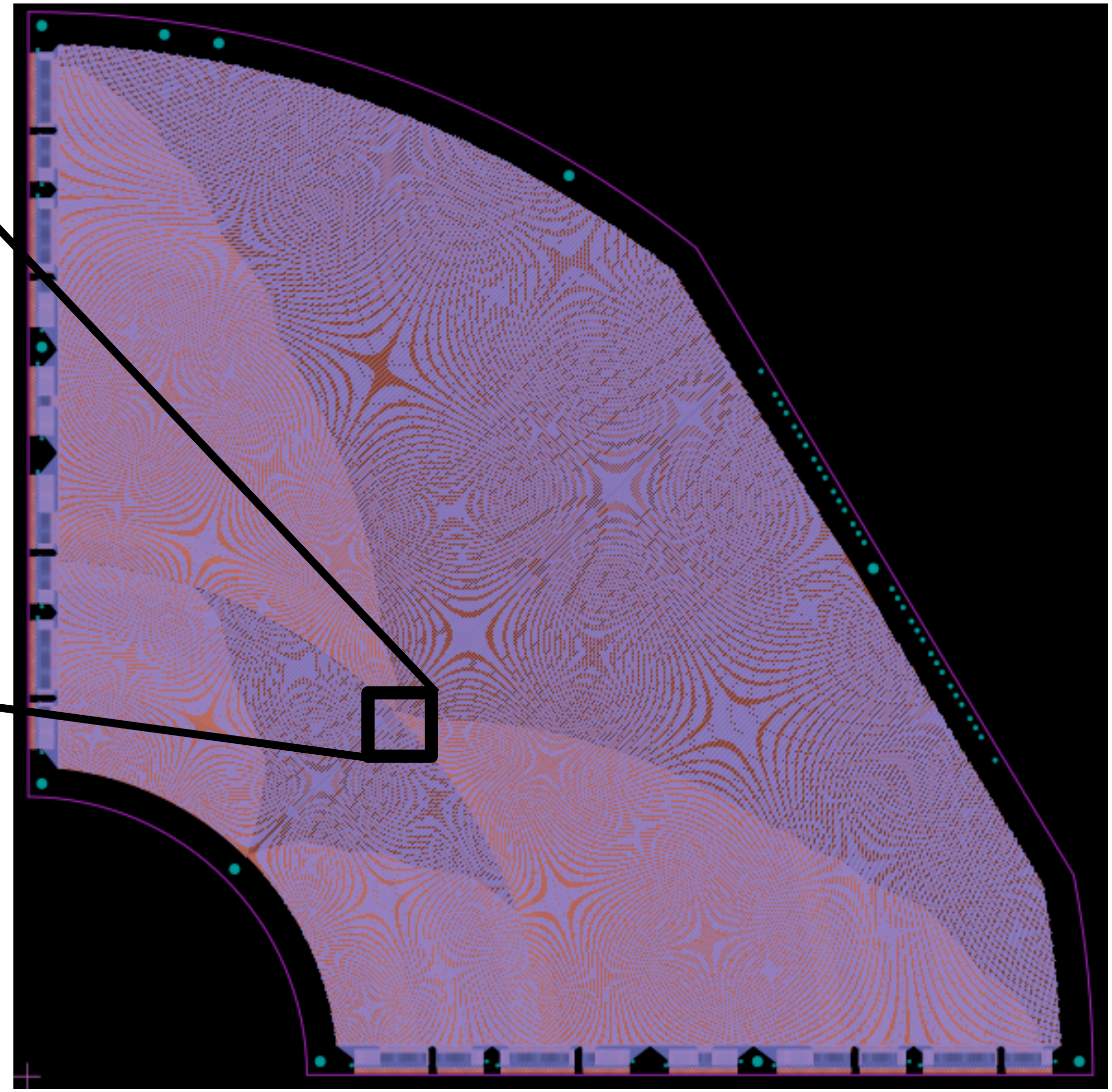
Triple-GEM Forward Tracking System - EIC R&D

- Forward system: Large 2D readout foil development - STAR Experience





- Commercial fabrication of 2D readout foil - New: Novel chemical etching technique by Tech-Etch Inc. - foil using VIAS connections)
- Next SBIR initiative: Extension of foil size

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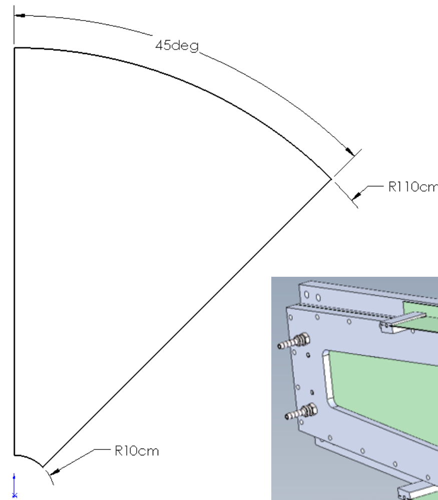
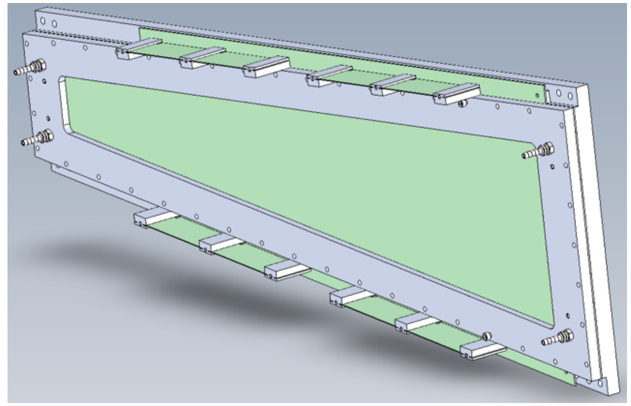
Bernd Surrow (MIT / Temple Univ.)

Triple-GEM Forward Tracking System - EIC R&D

- Forward system: EIC R&D
  - Specifications of a new EIC R&D prototype:
    - Dimensions: R ~ 10cm, L ~ 100cm, $\Delta\phi$ ~ 45°
      (R&D on size limitations and practicality of large foils)
    - Large GEM foil production
      (R&D on size extension - SBIR / First start with CERN single-mask foils)
    - Large 2D readout foil production
      (R&D on size extension - SBIR)
    - Mechanics
      (Frame, support requires R&R)
  - Request: 75k$ (FY12/FY13)
    - Labor: 50k$
    - Material: 25k$



OLYMPUS design



Building a full prototype segment essential:

- Mechanics
- Large GEM foils
- 2D readout foils
- FEE and connection

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Bernd Surrow (MIT / Temple Univ.)

Triple-GEM Forward Tracking System - EIC R&D

- Forward system: MIT/Temple group experience and resources
  - GEM foil production: Funded SBIR proposal
  - 2D readout board: Funded SBIR proposal
  - Mechanical design and assembly at MIT Bates
  - FEE design and testing at MIT Bates
  - Infrastructure (R&D Clean Room / Production lab) at MIT Bates
  - New infrastructure at Temple Univ.
    - New dedicated detector lab and separate Class 1,000 clean room in new science building
    - Optical CCD camera scan
    - Source scanning setup
    - X-ray source scanning setup
  - Extensive R&D
    - GEM foil production (Systematic comparison of CERN and Tech=Etch produced foils)
    - Prototyping (Standard size and large size)
    - Testing (Optical uniformity, Source scan, testbeam)

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Bernd Surrow (MIT / Temple Univ.)

Collaborative efforts - EIC R&D

- Examples of existing collaborative efforts
  - SBIR: BNL, Yale, MIT together with Tech-Etch Inc. (US DOE program)
  - ANR: French program to commercial certain aspects of MM production (CIREA)
  - Selected examples of collaborative GEM applications:
    - STAR: FGT (MIT and collaboration institutions) and upgrade
    - OLYMPUS: GEM Tracker (MIT and collaboration institutions)
    - DarkLight: Tracking system (MIT and collaboration institutions)
    - Hall-A (SBS Upgrade): Triple-GEM tracker (UVa: Kondo Gnanvo and Nilanga Liyanage)
    - CMS Upgrade (Myon System): Large foil production (FIT: Marcus Hohlmann, CERN: Archana Sharma)
  - Selected examples of collaborative MICROMEGAS applications:
    - COMPASS
    - CLAS12
    - T2K
    - SLHC
  - RD51 participation: Direct collaboration with R. de Oliveira was critical!

Collaborative efforts - EIC R&D

- Saclay / MIT-Temple Univ. R&D research plan and joined funding request

  - Funding request (FY12/FY13): $150k
    - Labor: $100k
    - Material: $50k

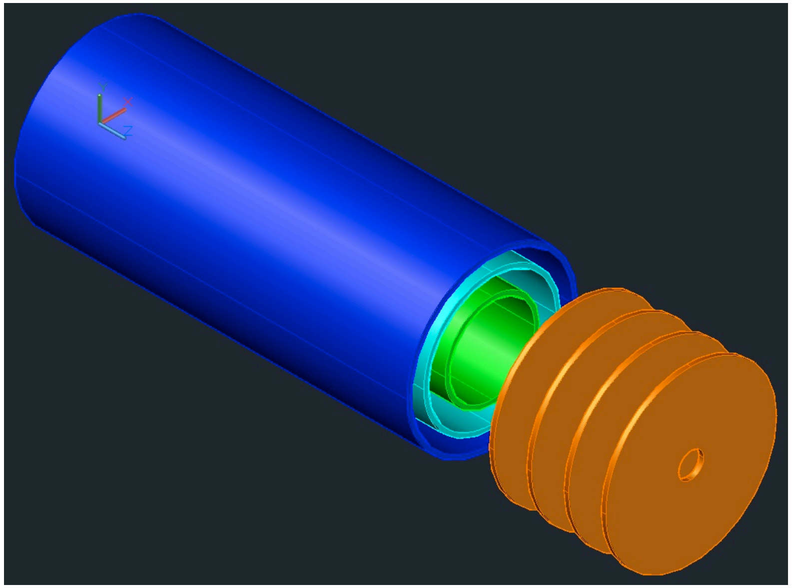
  - Research plan focus: FY12/FY13
    - Barrel: Production and testing of large cylindrical MICROMEGAS detectors and chip readout
    - Forward: Mechanical design and production and testing of large GEM foils (Initially CERN foils)

  - Long-term goals:
    - Commercialize large size components
    - Production and testing (Beam test) of full size prototype

  - Essential component: Build and test full size prototype collaborating directly on test equipment, resources incl. man-power and FEE development

Summary

- Summary
  - Joined proposal focusing on micro-pattern technology concerning one part of tracking system (LOI)
  - Extensive previous experience and resources
  - MICROMEGAS / GEM technology: Well-suited for EIC application providing a cost-effective solution
  - Intensify collaboration between US / European institution at various levels
  - Success replies on adequate support in particular labor support
  - Collaboration / communication with other R&D efforts essential on overall tracking system (LOI) and simulations efforts



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